Integrated Active Desiccant Rooftop (IADR) Product Development

2003 DOE Peer Review: Presented by John Fischer

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Project Objectives

- Develop a cost competitive, compact and highly efficient integrated active desiccant – DX packaged rooftop system capable of decoupling the latent load from conventional HVAC packaged systems
- Offer an energy efficient way to accommodate ASHRAE 62 recommendations, while controlling space humidity and utilizing gas or waste heat generated by CHP applications for regeneration
- Combine the energy efficiency of a total energy recovery wheel with the “low dewpoint” capability of an active desiccant wheel into Rooftop unit

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Project Team Members

- **SEMCO Inc.**
  - John Fischer, Program Manager
  - Various others in engineering and R&D
- **UIC**
  - Doug Kosar, wheel and systems modeling
  - Dr. Bill Worek, wheel matrix optimization
- **C&M Engineering**
  - Kirk Mescher P.E., design investigation
- **ORNL**
  - Dr. Jim Sand Program manager

IADR Program Progress:

Milestone	Completion Date
1) Initiate CHP candidate building analysis	**9/30/01**
2) Initiate building design and benefit analysis	**9/30/01**
3) Complete building analysis and Task 1 report	**1/01/02**
4) Complete benefit analysis and Task 2 report	**2/01/02**
5) Initiate definition of active hybrid system	**2/01/02**
6) Complete product definition and Task 3 report	**4/01/02**
7) Define controls strategy and Task 4 report	**5/30/02**
8) Initiate wheel performance optimization	**5/30/02**
9) Finalize wheel optimization and Task 5 report	**10/30/03**
10) Begin production of prototype system	**9/30/02**
11) Finalize prototype production	**12/01/02**
12) Begin lab testing of prototype system	**1/01/03**
13) Finalize testing of prototype	**8/01/03**
14) Final report delivery	**12/30/03**

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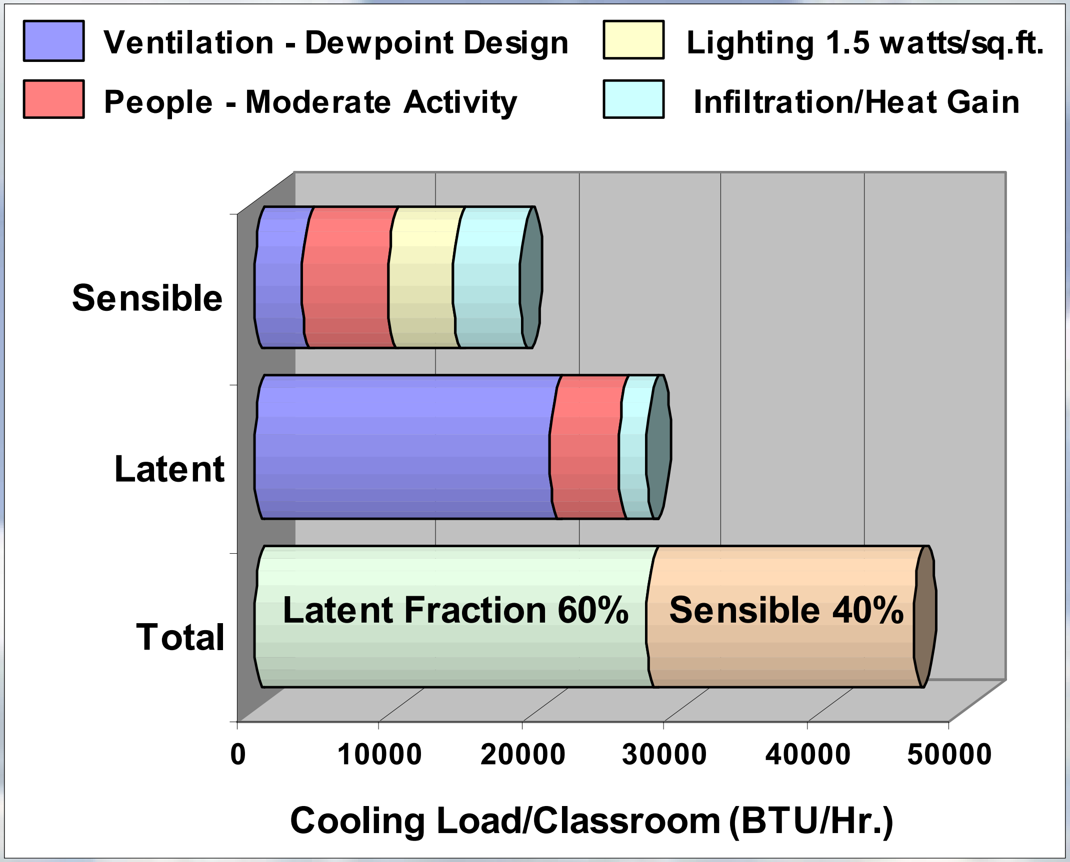
Background Establishing the Market Driven Need for this Technology

Impact of Standards on Energy Consumption in Commercial Buildings

- ASHRAE Standard 62: Increases the quantity of outdoor air, delivered continuously, to maintain an acceptable indoor air quality
- Conditioning outdoor air involves primarily latent load (humidity) during peak design
- The ASHRAE 90.1 Energy Code increases lighting efficiency thereby significantly decreasing the space sensible heat ratio (SHR)

Cooling Load in Typical Classroom with ASHRAE Standards 62 and 90.1



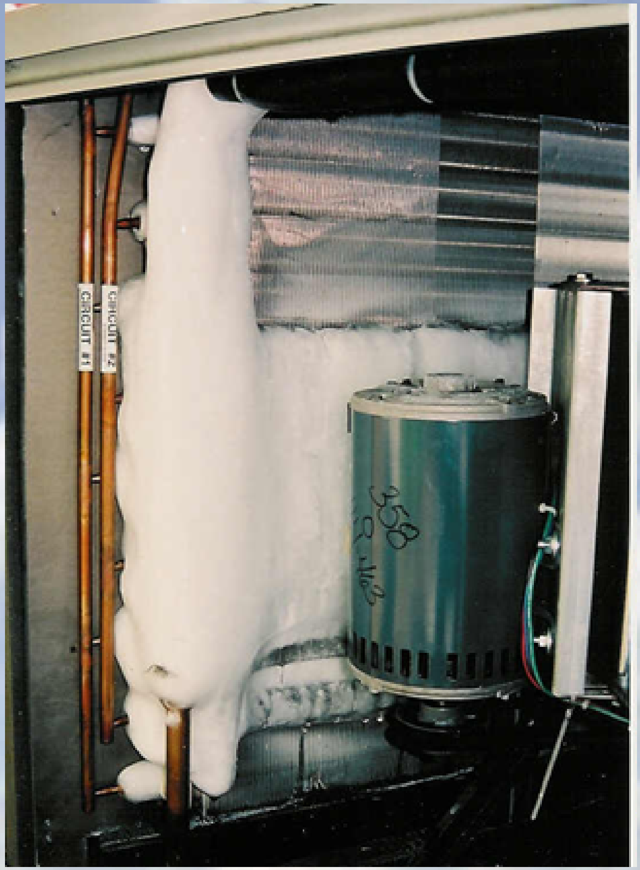
Source: May 2003 ASHRAE Journal Article "Report Card on Humidity Control"

Energy Efficiency and IAQ Code: On a Collision Course

- Significant increase in outdoor air quantities will mean huge escalation in energy consumption without new design approaches
- Packaged equipment, used for 90% of all buildings, can not accommodate the increased outdoor air quantities without creating humidity problems or using reheat
- Reheat further increases energy consumption

Over-sizing Packaged Units to Handle Outdoor Air is Problematic

- Not designed for more than approximately 15% outdoor air
- If fan runs continuously, moisture evaporates off of the cooling coil when the compressor is off
- Poor humidity control
- Frozen coils at part load conditions



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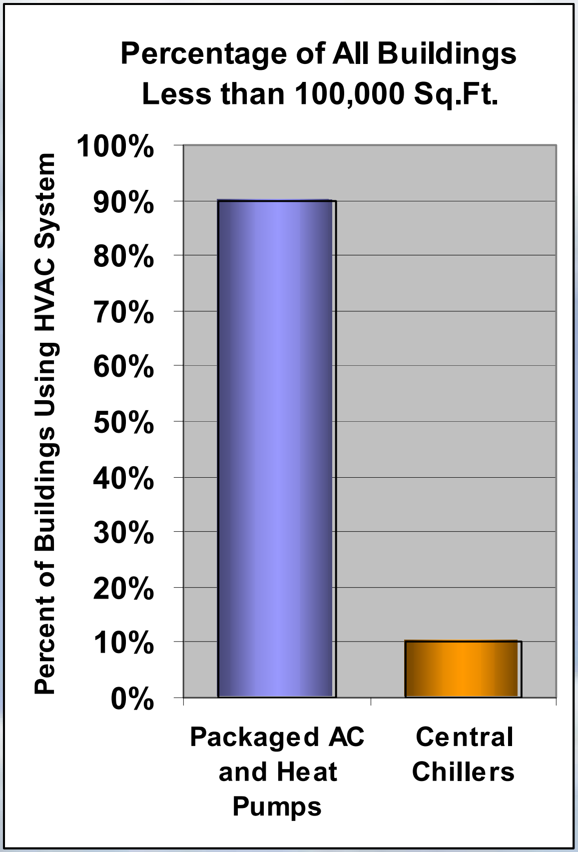
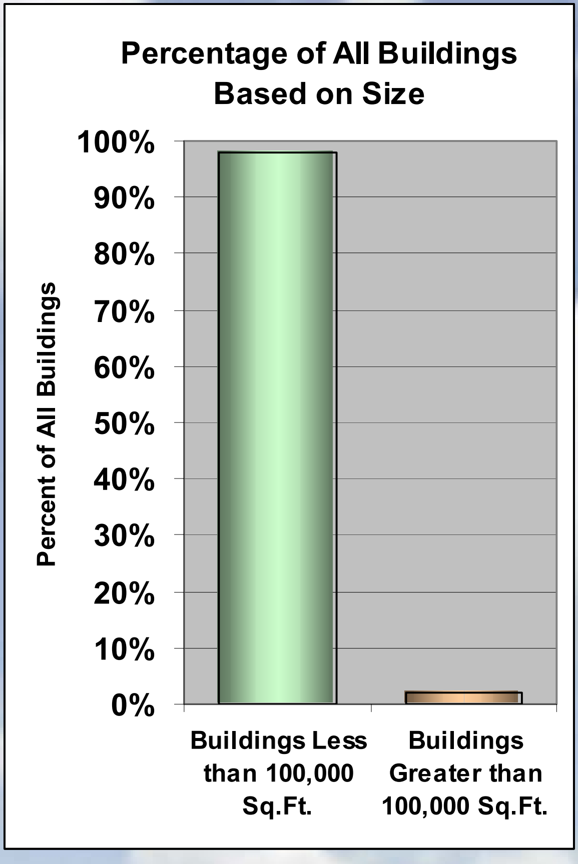
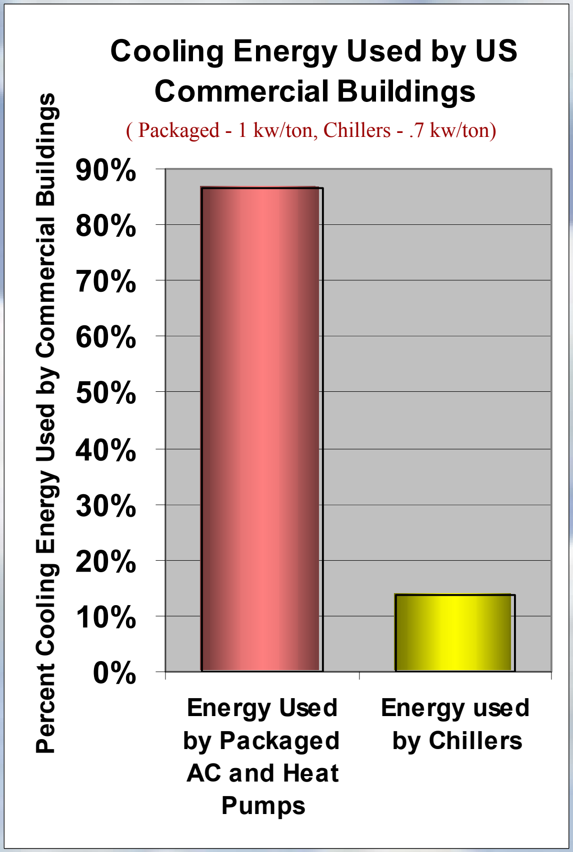
Dominance of Packaged AC Equipment







Source: DOE 1999 Commercial Buildings Energy Consumption Survey

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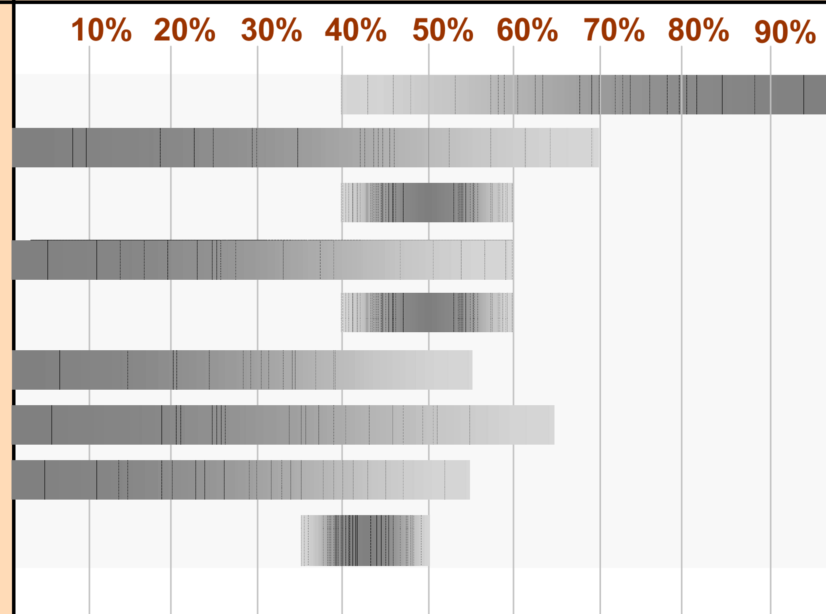
Many Reasons for Controlling Humidity

Control School Humidity Levels to Limit:	Recommend Space Humidity Range (Relative Humidity)	Source
Respiratory Infections		4,6,7
Mold and Fungi Problems		2,8
Infectivity of Bacteria and Viruses		2,5,8
Formaldehyde Off-gassing		1
Asthma and Allergic Reactions		8
Comfort Complains		3
Perceived Air Quality Complaints		3
Book Damage in Libraries		9
Warpping of Hardwood Floors (Gymnasium)		9
ASHRAE Recommend Range (Standard 62-1999)	**30% - 60% Relative Humidity**	**2**



Source: May 2003 ASHRAE Journal Article "Report Card on Humidity Control"

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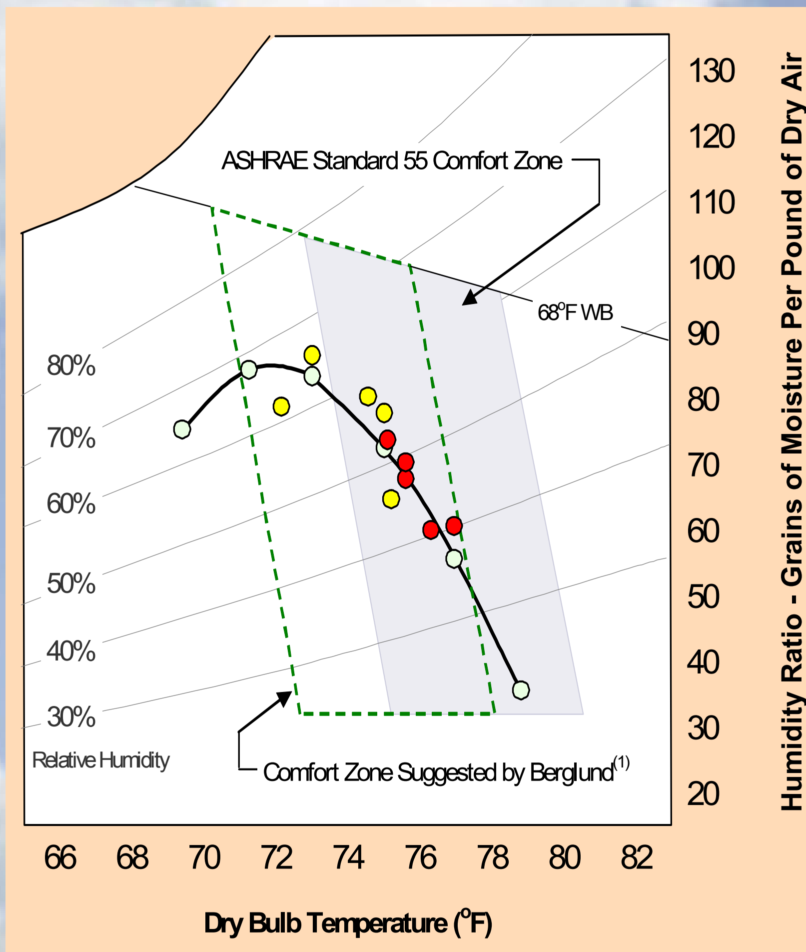
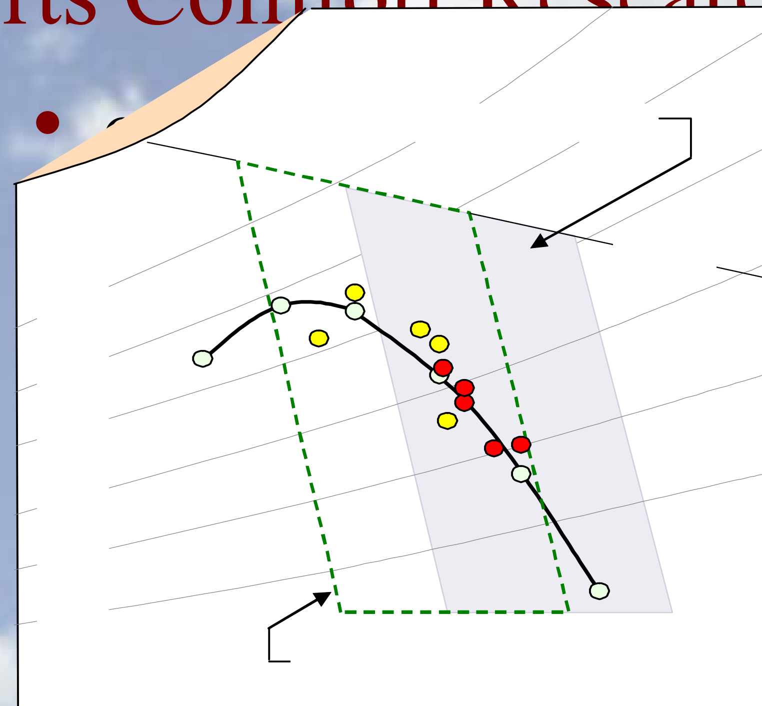
Schools Data Supports Comfort Research





Humidity Handbook

- Berglund ASHRAE article: Conditions for 90% thermal acceptability
- Average cooling season space conditions from DOE investigation for schools using conventional (non-desiccant) systems
- Average cooling season space conditions from DOE investigation for schools using non-conventional (desiccant) systems

Source: May 2003 ASHRAE Journal Article "Report Card on Humidity Control"

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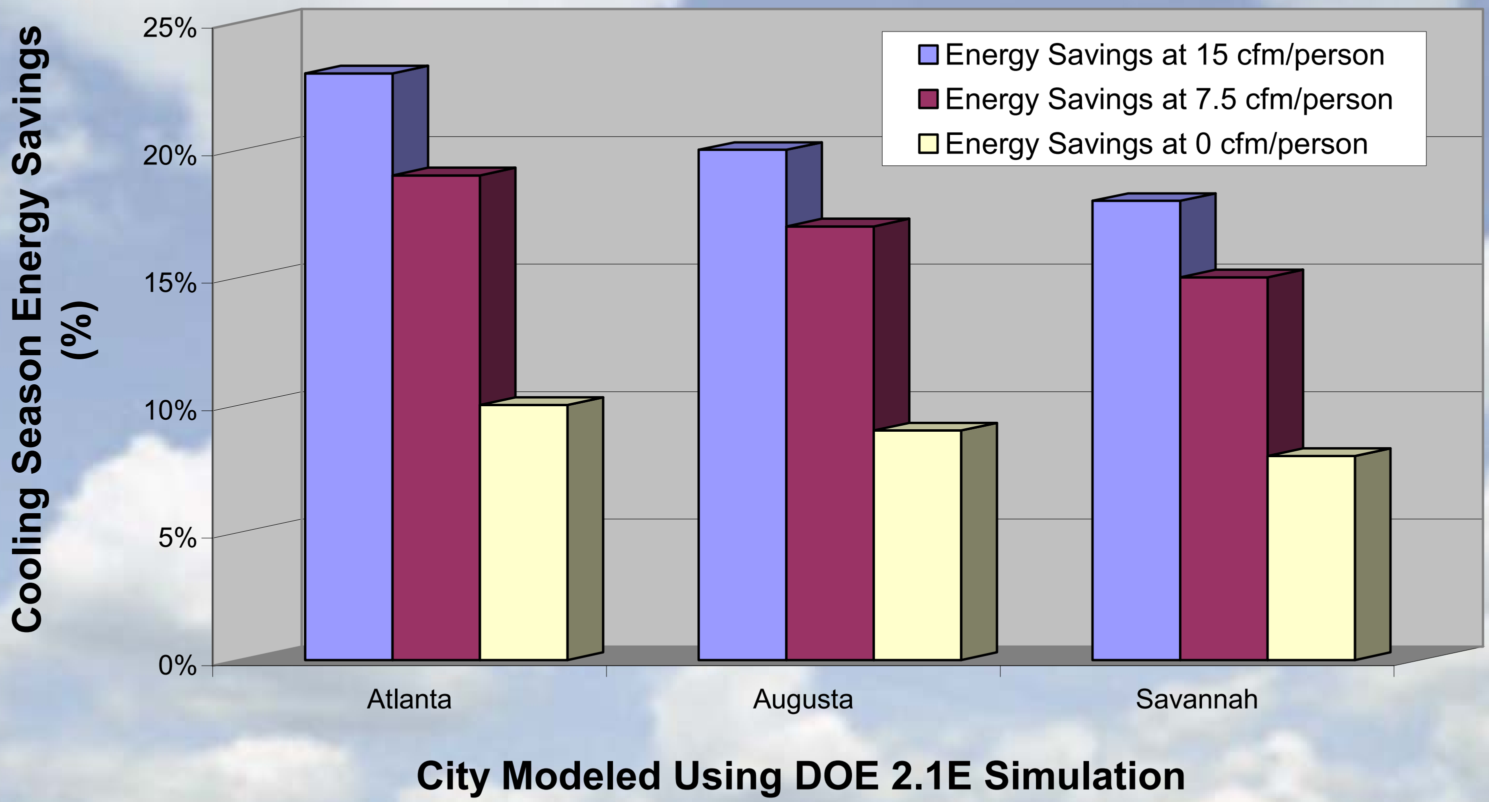
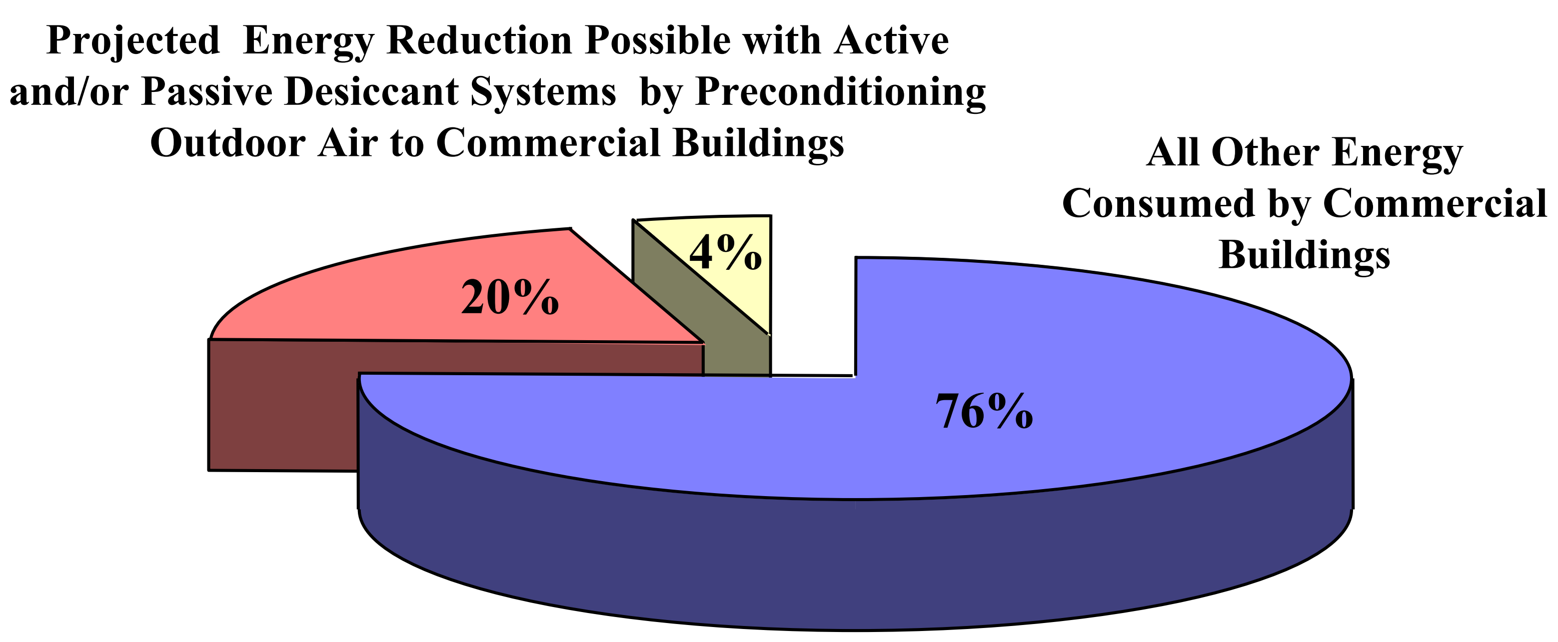
Energy Savings with 2º Rise in Space Setpoint Temperature



Energy Impact: Ventilation Air



U.S. Commercial Buildings Energy Consumption Increase Over 10 Years:

DOE Projected Base Energy Increase: Years 1990 to 2000 (1.31 Quadrillion BTU)

SEMCO Phase 1 Report: ORNL/SUB/94-SV044/1

SEMCO Integrated IADR

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Technical Barriers/Challenges

- Optimize the performance of an active desiccant – DX refrigeration hybrid while minimizing size, first cost and parasitic energy use (wheel pressure loss)
- Optimize the refrigeration section for peak energy efficiency and integration with the desiccant wheel
- Design a high performing, low cost direct gas fired regeneration source while accommodating hot water
- Develop a cost effective control system to take full advantage of the hybrid systems capabilities
- Easy and cost effective integration of a passive desiccant total energy recovery

Full Laboratory Testing:

(Complete System Testing in the SEMCO Air Test Lab)

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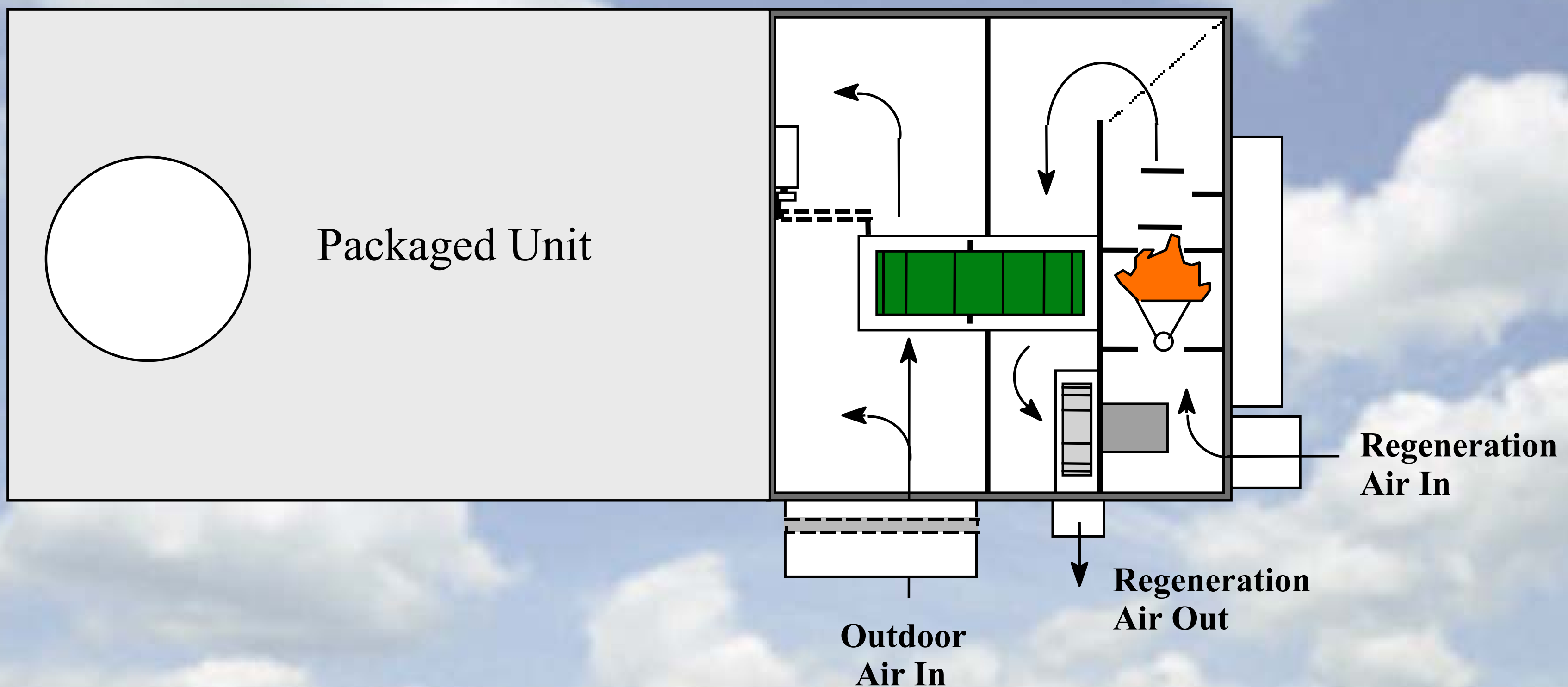
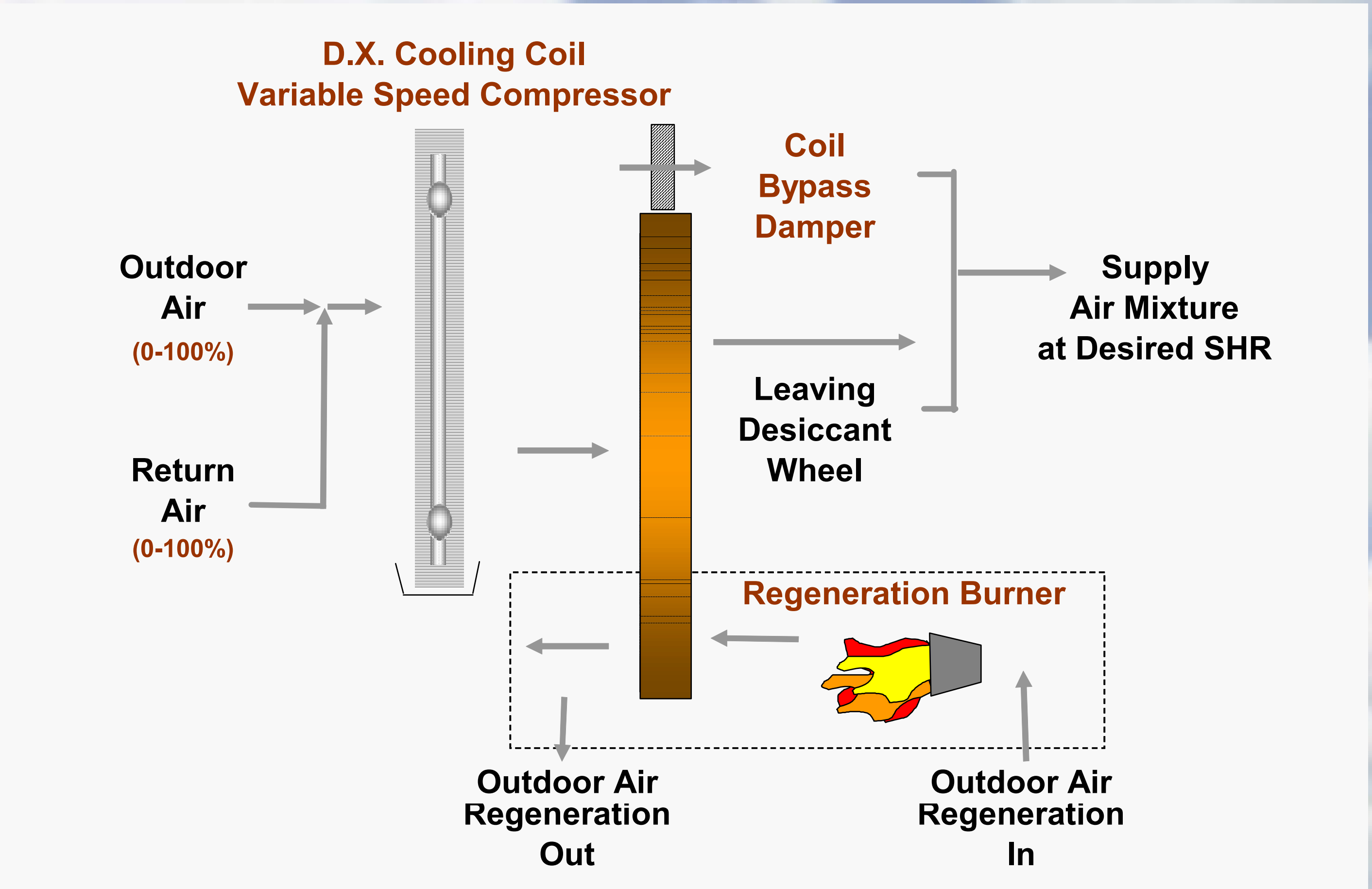
Previous Active Desiccant Systems Installed Upstream of the Cooling Source



Previous Active Desiccant Systems

- All of the outdoor air processed by active desiccant wheel in this arrangement (not sweet spot)
- Large moisture removal required meaning high regeneration temperatures and low face velocities
- High heat of adsorption requires significant post cooling or second sensible recovery wheel
- Results in a large active desiccant wheel and large overall system with a high manufacturing cost

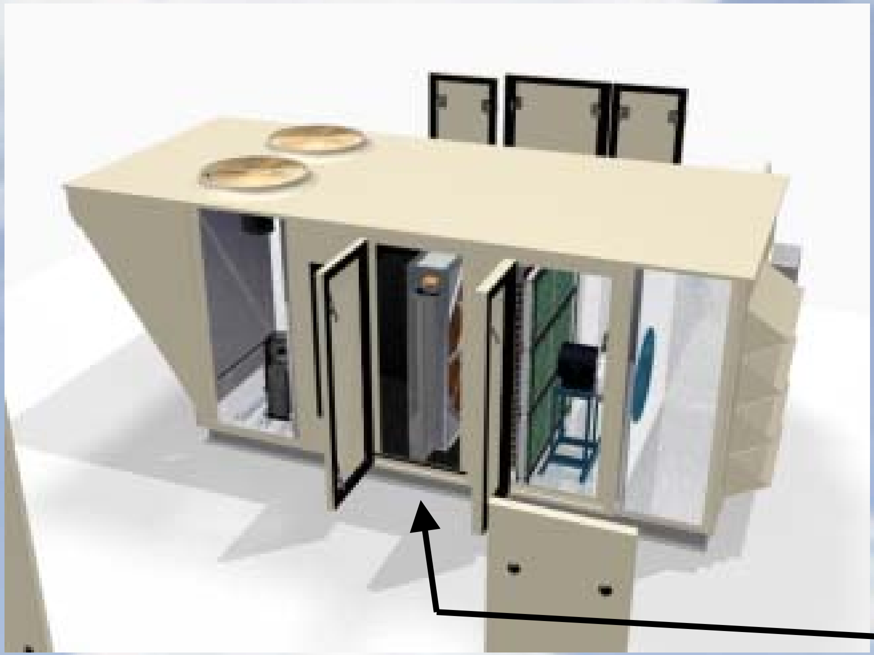
IADM Approach: Flow Schematic



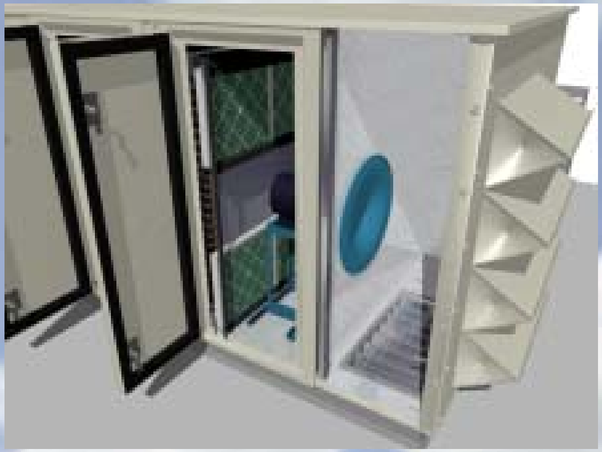
Advantages of IADR Approach

- Much smaller desiccant wheel processing only a fraction (1/2 to 1/5) of the supply air stream volume
- Much smaller system size, matching existing packaged rooftop equipment expectations, lower cost
- Greatly reduced energy consumption and required regeneration temperature (excellent CHP integration)
- Can produce drier air than other approaches (DOAS)
- More control options to accommodate all conditions

IADR: The Supply Air Side



Supply side of IADR showing outdoor air intake, filters, evaporator coil, active desiccant wheel and integrated condensing section with variable speed scroll compressors



Outdoor air intake/return section with variable speed supply air fan

Integrated Active Desiccant Wheel

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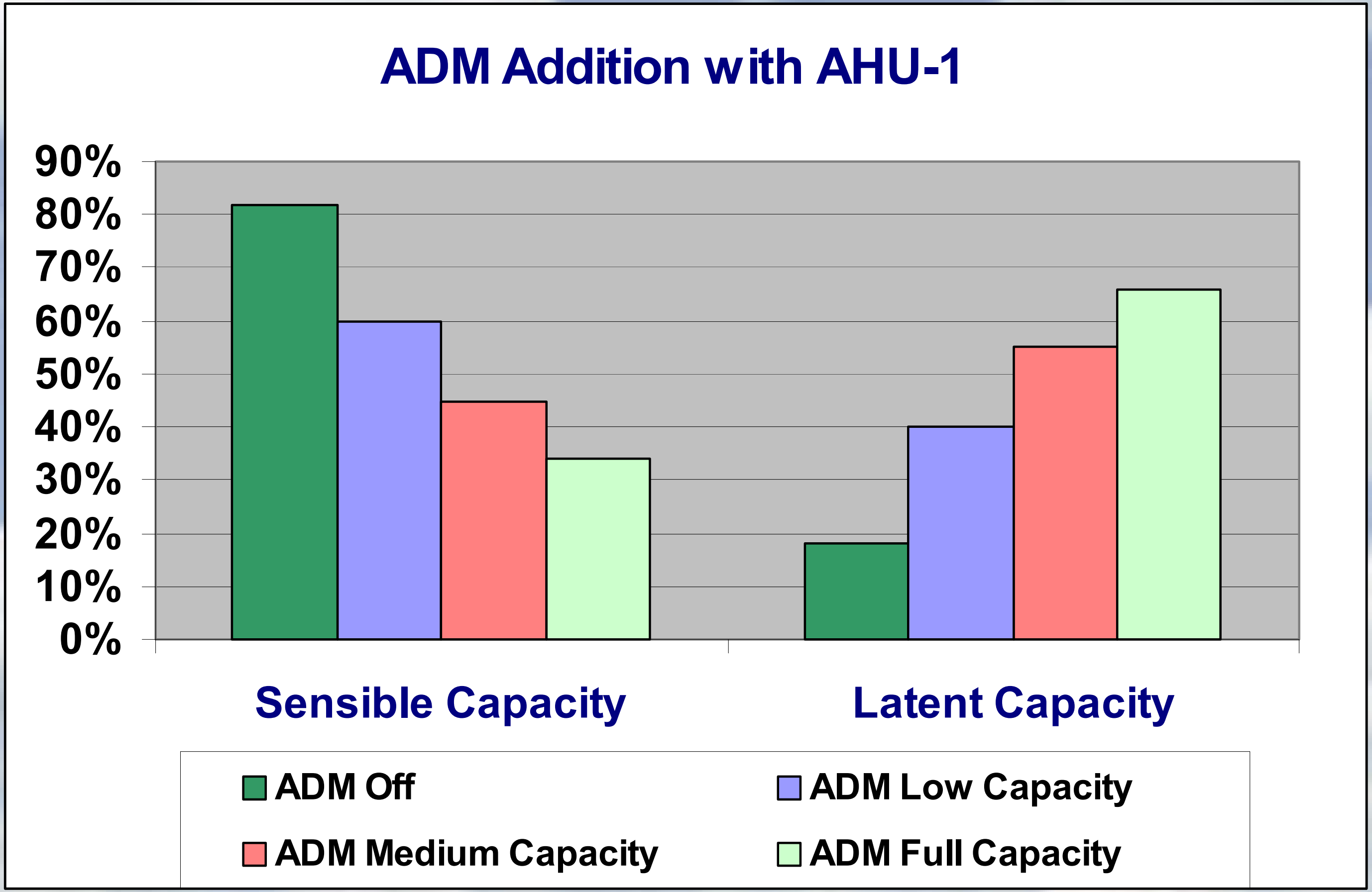
IADR: The Regeneration Side

Regeneration side of IADR showing burner section inlet and outlet, electrical and control panels as well as the condensing coils and fans

Outdoor intake section

Cut-away showing dual direct gas fired modulating burners

With Modulation the ADM Can Vary the Sensible and Latent Capacity Delivered



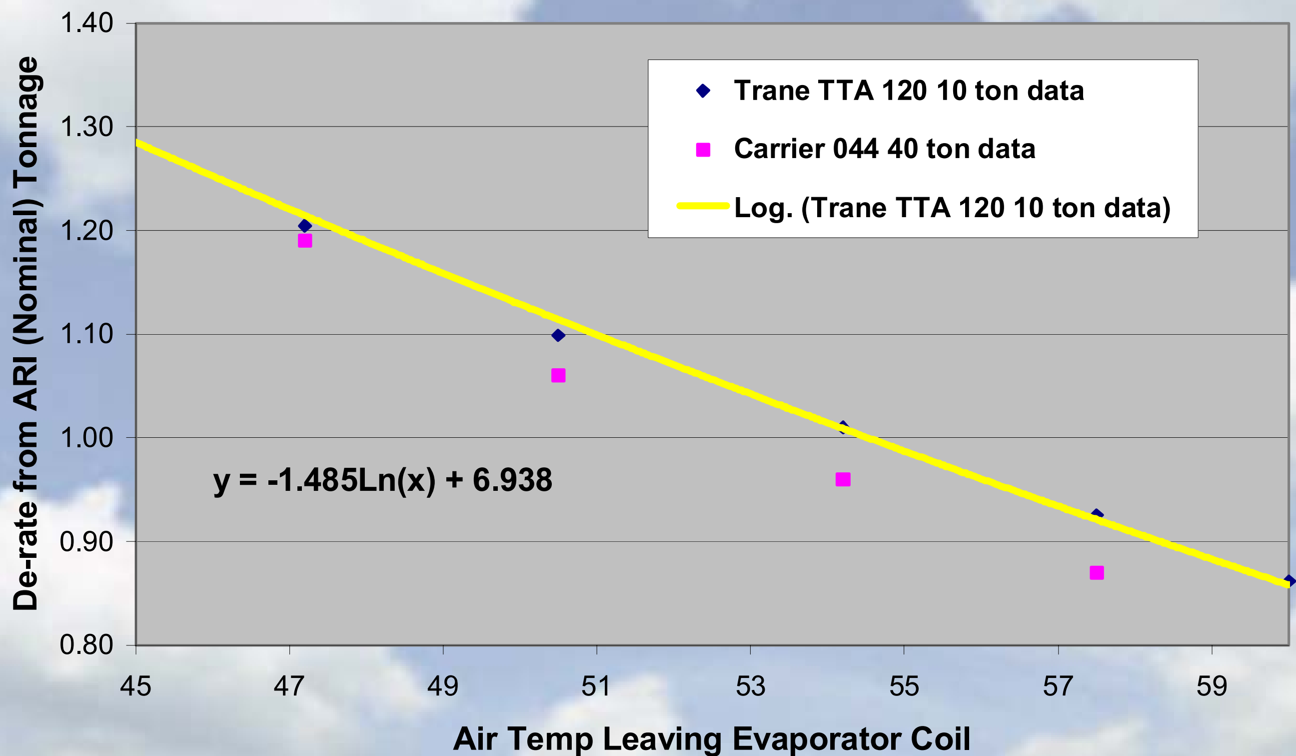
IADR: Leap Frog Capabilities

- Compact size, fully integrated system (active desiccant, refrigeration and controls) easy to engineer and install
- Accommodates any outdoor air percentage (0-100%) and provides variable SHR
- Exceptional humidity control (variable speed compressor)
- Energy efficient delivery of low dew point outdoor air (100 grain depression possible)
- Variable outdoor air volume capability for demand control ventilation
- CHP compatible requiring moderate regeneration energy quantities and temperatures – excellent match with IC engines
- Ability to cosorb indoor and outdoor air pollutants

High System Operating Efficiency

- Processes air streams to moderate leaving coil temperatures, allowing active desiccant wheel to further depress the dew point
- Variable speed compressor “off-loads” capacity at part load conditions evenly and efficiently, unlike hot-gas bypass or compressor cycling
- No reheat energy required for dedicated outdoor air (DOAS) applications
- Gas or waste heat (CHP) for regeneration

Condensing Unit Performance Adjustment Based on Coil Leaving Air Temperature



The equation corrects the calculated cooling capacity input for 95 degree ambient and suction temperature

Analyses based on a Heatcraft coil 5EN1205B, 3000 cfm, 80db/67wb entering, 42H x 26W, 396 feet per minute

Office Building Jefferson City Mo.
(used for baseline engineering evaluation)

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Engineering Analysis: Government Office Building

PACKAGED ROOFTOP UNIT SCHEDULE											
APPROACH	SIZE	FAN		COOLING COIL		BURNER	ELECTRICAL			MIN O. A.
		CFM	HP	TOTAL MBTUH	SENSIBLE MBTUH	INPUT MBTUH	V	PH	MCA	
Base RTU	105 Tons	32,550	50	1222	938	945	460	3	283	4000
BASE W/ERU RTU	90 Tons	31000	50	1051	876	938	460	3	262	4000
DESICCANT HYBRID	60 Tons	27000	40	749	727	650	460	3	165	4000
REDUCTION FROM BASE	43%	17%	20%	39%	22%	31%			42%	

Results of comparison made between a conventional packaged system, a packaged system combined with total energy recovery and an IADR active desiccant/total energy recovery hybrid system

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Hybrid System Can Be Cost Effective

PACKAGED ROOFTOP UNIT SCHEDULE					
APPROACH	PACKAGE UNIT SIZE	PACKAGE UNIT COST	ER OR HYBRID COST	COMBINED COST	SIMPLE PAYBACK
Base RTU	105 Tons	$78,900	N/A	$78,900	N/A
BASE W/ERU RTU	90 Tons	$72,400	$11,000	$83,400	1.5 YEARS
DESICCANT HYBRID	60 Tons	$46,500	$37,400 (3)	$83,900 (2)	1 YEAR (1)
REDUCTION FROM BASE	43%	41%			

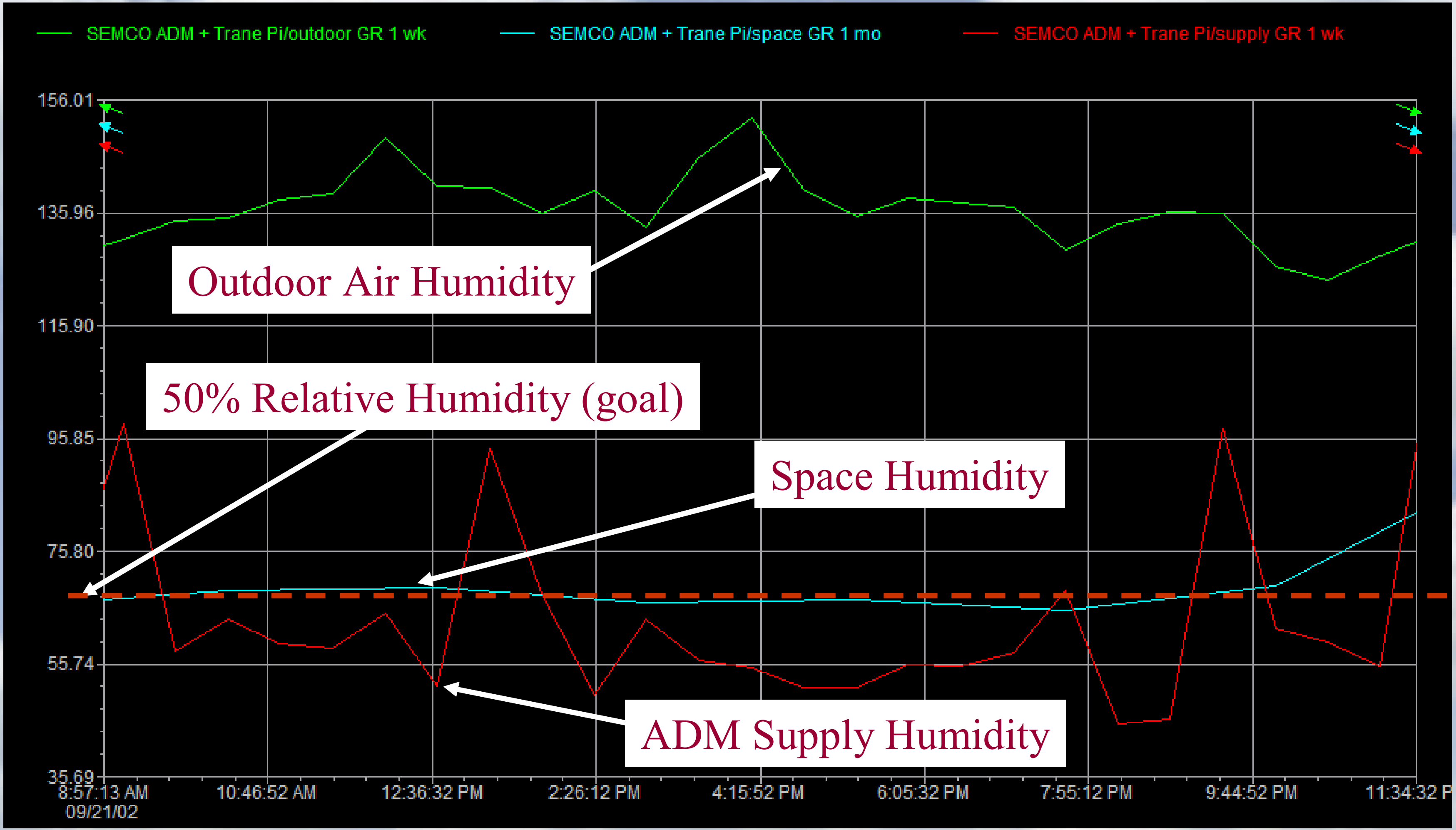
Note 1: Assumes payback of one year to determine necessary selling price
Note 2: Combined sales price based on a one year payback and estimated savings of $5,500/year for the active desiccant – total energy recovery hybrid system
Note 3: Necessary selling price for a 4,000 cfm active desiccant – total energy recovery hybrid based on assumptions

Restaurant Pilot Installation

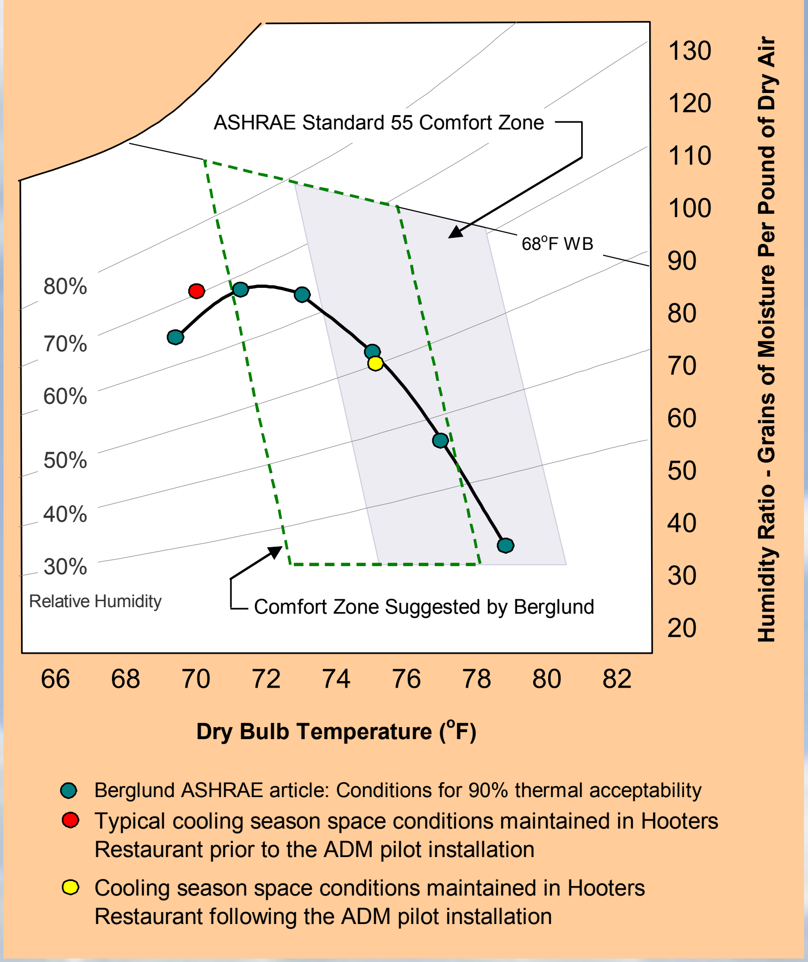
ADM Add On Active Desiccant
Module

Fresh, Dry Outdoor Air for Kitchen Exhaust Makeup and ETS

All Pilot Sites Remotely Monitored

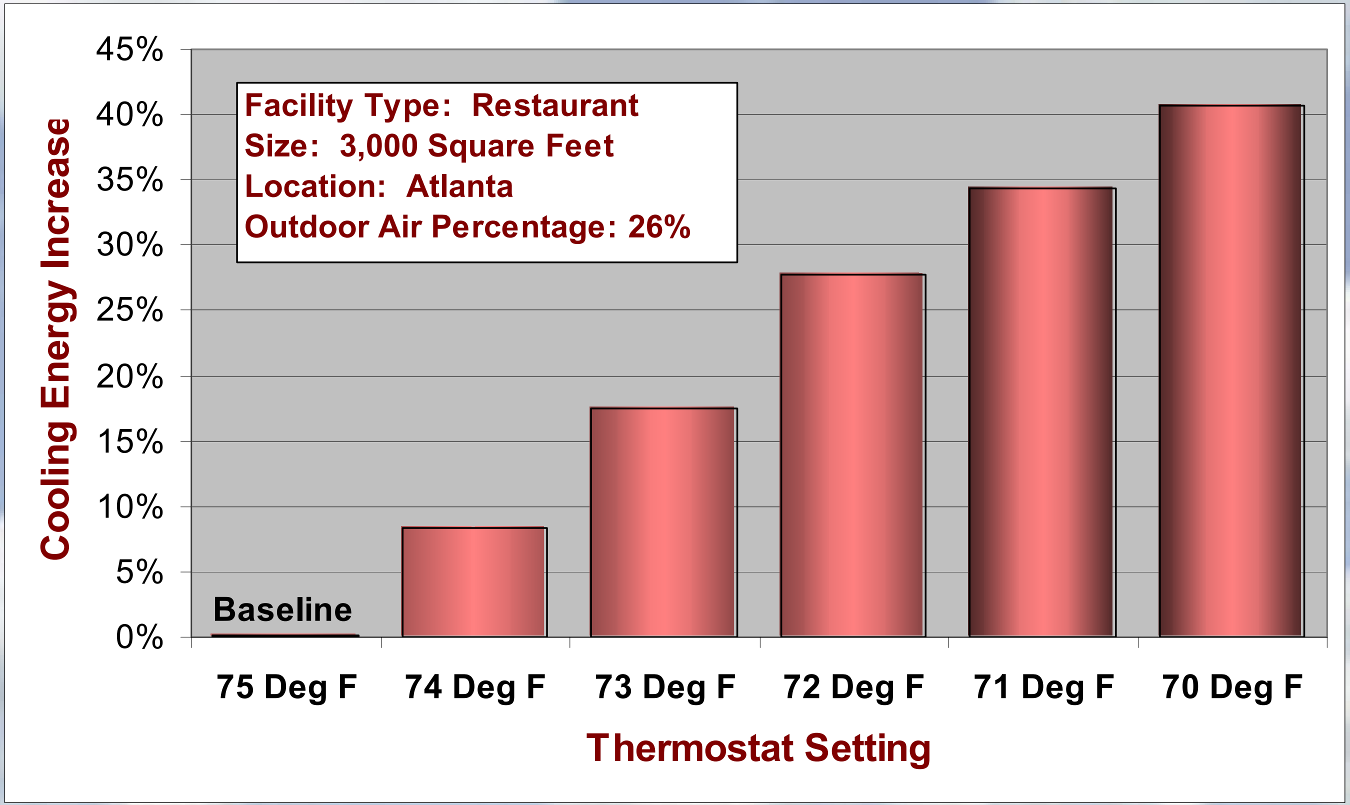


Successful Restaurant Pilot



- Reduced total electrical cost by approximately 15% equating to a 29% reduction in cooling energy costs
- Raised space thermostat setting by 5 degrees while improving comfort due to humidity control
- Improved IAQ and reduced window condensation
- Easily retrofitted to existing facility

Lower Thermostat Settings Significantly Increase Cooling Energy Consumption



Source: DOE 2.1 modeling completed by Doug Kosar of UIC.

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Movie Theater Pilot Installation

IADR Systems Installed as Dedicated Outdoor Air Systems

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Theater Pilot Project: Support from The American Gas Foundation

IADR 4500 Installed at Theater

One of two 4,000 cfm all outdoor air systems serving the facility

IADR Applied as a Dedicated Outdoor Air System

ADM Model: Movie Theater DOAS ***Model Selected: IADM 4500***

0

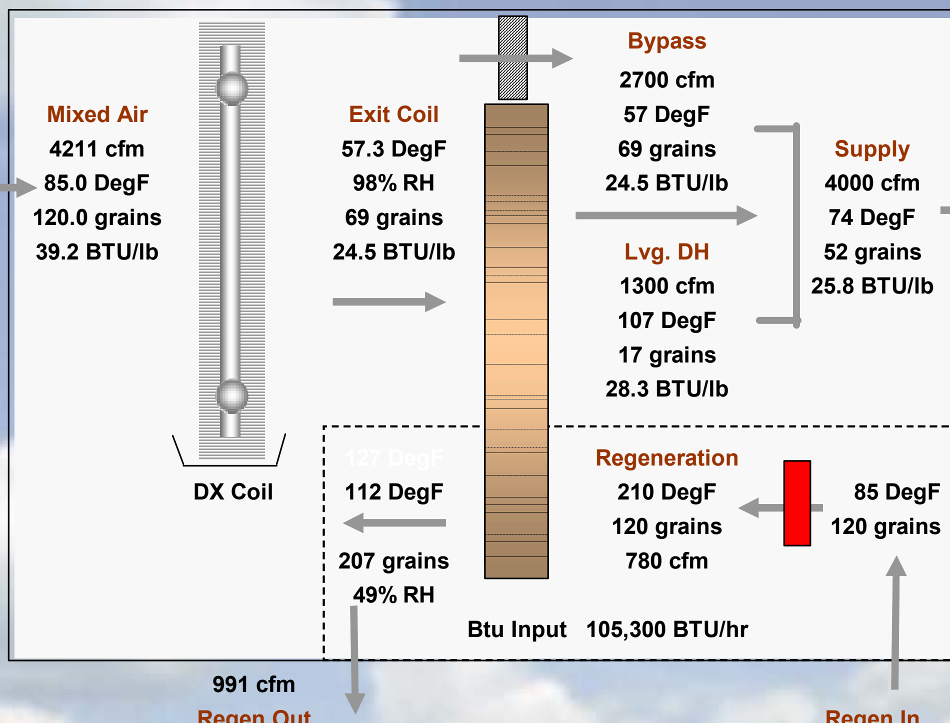
Inputs

Outdoor Air
4211 cfm
85.0 DegF
120.0 grains
39.2 BTU/lb

Return Air
0 cfm
77.0 DegF
65.5 grains
28.7 BTU/lb

Supply Grain Level
51.9 grains
0 grains

Bypass %
68%



Ouputs

DX Tons Input
21.6 tons

DX Tons Output
23.3 tons

Max Regen Input
105,300 BTU/hr

Supply Conditions
74 DegF
52 grains

Latent Cooling Delivered
15.4 tons

SHR
0.2

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IADR vs. Conventional DOAS

	IADM	Packaged System	Packaged System with Reheat
Sensible load required Latent load required SHR	46,224 BTU/Hr 186,492 BTU/Hr 0.20	46,224 BTU/Hr 186,492 BTU/Hr 0.20	46,224 BTU/Hr 186,492 BTU/Hr 0.20
Sensible load delivered Latent load delivered SHR	49,592 BTU/Hr 186,409 BTU/Hr 0.21	161,136 BTU/Hr 87,917 BTU/Hr 0.65	46,224 BTU/Hr 186,492 BTU/Hr 0.20
Space humidty peak load Space humidity part load	50% 50%	NA NA Can not operate at DOAS	50% 50%
Space temperature needed to reach occupant comfort	75.2 DegF	NA NA	75.2 DegF
Tons needed for latent load Reheat energy required Regeneration energy	21.6 tons 0 BTU/Hr 105,300 BTU/Hr	NA (Tons typically installed)	33.6 tons 107,231 BTU/Hr 0 BTU/Hr

Conditioning 4,000 cfm from 85^{o}F/120 grains to 74^{o}F/52 grains, packaged unit overcools to reach dew point

Application Advantage of IADR

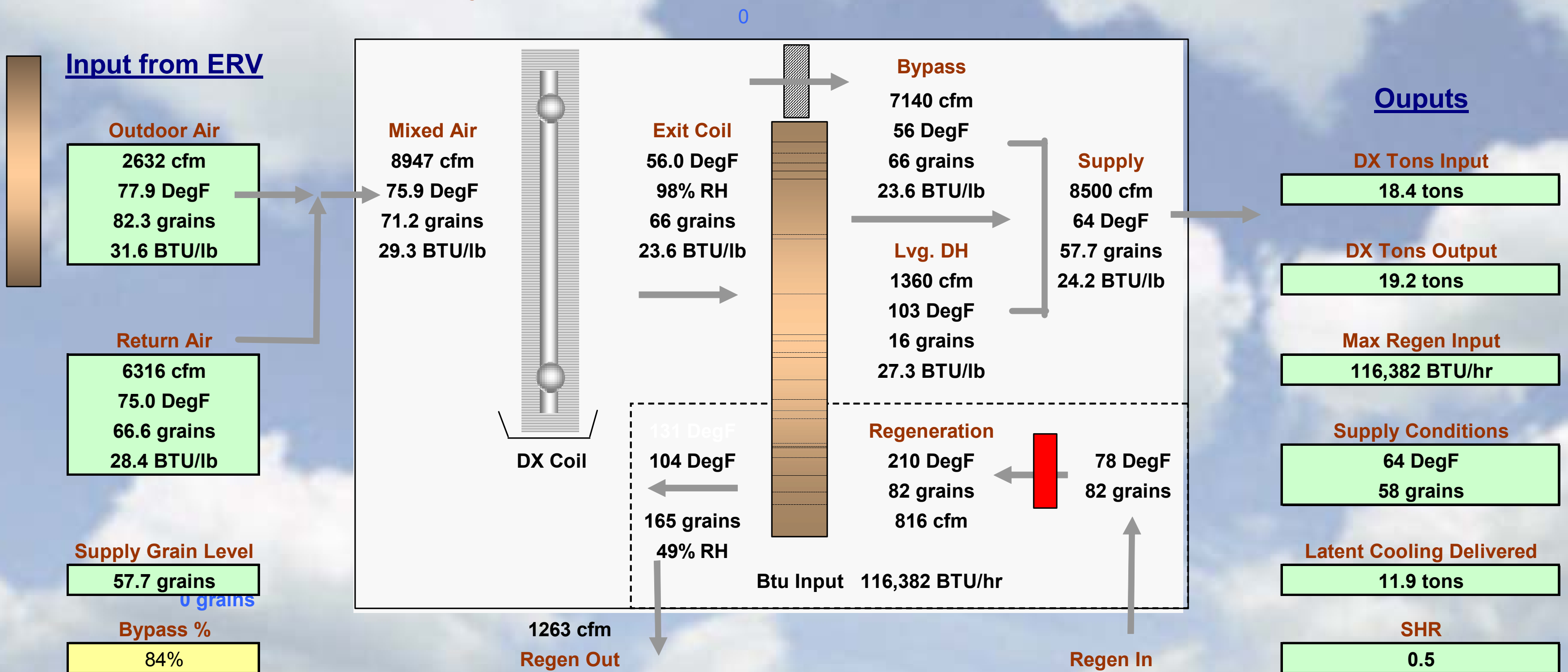
- The IADR can be applied as a dedicated outdoor air system (DOAS)
- The IADR can also be applied as a total conditioning system functioning as the DOAS and the space conditioning system
- The IADR can also function as a true VAV system to optimize both space temperature and humidity levels

School Pilot Installation

IADR Systems Installed as a Total Conditioning VAV System

IADR as a Total Conditioning System

ADM Model: School Facility *Model Selected: IADM 6000*



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IADR with ERV vs. Conventional

	IADR	Packaged System	Packaged System with Reheat
Sensible load required Latent load required SHR	107,600 BTU/Hr 142,363 BTU/Hr 0.43	107,600 BTU/Hr 142,363 BTU/Hr 0.43	107,600 BTU/Hr 142,363 BTU/Hr 0.43
Sensible load delivered Latent load delivered SHR	112,751 BTU/Hr 142,363 BTU/Hr 0.44	221,400 BTU/Hr 94,782 BTU/Hr 0.70	107,600 BTU/Hr 142,363 BTU/Hr 0.43
Space humidty peak load Space humidity part load	50% 50%	79% 79%	50% 50%
Space temperature needed to reach occupant comfort	75.2 DegF	71.1 DegF 71.2 DegF	75.2 DegF
Tons needed for latent load Reheat energy required Regeneration energy	18.4 tons 0 BTU/Hr 116,382 BTU/Hr	25.0 tons (Tons typically installed) Humidity Conditions Not Met with this standard selection!	33.5 tons 128,157 BTU/Hr 0 BTU/Hr

Conditioning 8,500 cfm, 20% outdoor at 85^{o}F/120 grains to a supply air condition of 64^{o}F and 58 grains (51^{o} dew point)

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Numerous Pilot Candidates Identified: Market Pull for Technology is Strong

- Restaurant Chain – Completed
- Resort Hotel – Completed
- Major Movie Theater Group – Installed
- Large School District – Underway
- Major Retail Pharmacy Chain – Finalizing
- Major Fast Food Chain
- Nursing Home Group

Public – Private Partnerships

- ORNL/DOE – Product management and CHP Lab testing (2004)
- University of Chicago at Illinois – Wheel research
- Georgia Tech Research Institute – IAQ research
- American Gas Foundation – support of pilot sites
- Gas Utilities – support with pilot sites and national accounts
- ASHRAE – published Journal article

Impact on DER and TAT Programs

- The IADR is an active desiccant system that can improve IAQ and humidity control while also reducing energy consumption
- TAT packaged system approach that can serve 90% of the HVAC marketplace
- IADR design matches well with both the temperature and quantity of waste heat generated by IC engines and micro turbines

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IADR Matches the DOE Road Map

TABLE 4-1. INDOOR ENVIRONMENTAL QUALITY AND SECURITY
Strategic Goals

<table>
<tr>
<td>By 2005, create category in waste heat accounting for exhaust air from buildings and processes.</td>
<td>By 2005, develop a program to account for BTUs saved/captured (efficiency improvement). This is looking at system savings –vs- equipment savings.</td>
<td>By 2005, develop cost effective 500-3000 CFM liquid desiccant packaged unit for space, heating, cooling and humidity control. (stand alone units. Added benefits for particle and bacterial removal)</td>
<td rowspan="4">Develop improved black box solutions for recovered heat.

Black Box
– Any building
– Any climate
– Any prime mover
– Heating/DHW
– Cooling/Humidity control
– Air quality/ventilation

Black Box Control/Demand-Control Ventilation

– Temperature
– Humidity
– CO2
– Particulate
– Gases (VOC, Bio, Weapons
– Air motion
– Acoustics
– Energy

Temperature Range and Time
< 100F --------- 20xx
100-130F-------20xx
130-220F-------20xx
220-600F-------20xx
>600F-----------20xx</td>
</tr>
<tr>
<td>By 2008, develop building system with minimized parasitic losses from air mover and pumps.
- OSA and exhaust are only air moved
- CHP and desiccants treat OSA</td>
<td>By 2008, optimized desiccant integrated CHP system that uses active desiccant technology to adsorb/absorb airborne contaminants from indoor/outdoor air.</td>
<td rowspan="3">By 2005, develop cost effective (customers will buy it) 3000-20,000 CFM liquid desiccant ventilation air pre-conditioner for commercial and institutional buildings.

By 20xx, develop liquid desiccants that can be used to store thermal energy.</td>
</tr>
<tr>
<td>By 20xx, institute an Emissions Tax/Credit for energy efficient buildings. (sell/trade credits).</td>
<td>By 2005, develop/commercialize an integrated rooftop (active/passive desiccant/vapor compression) that allows variable sensible/latent heat ratio that is cost effective.</td>
</tr>
<tr>
<td>By 20xx, adapt a green building approach that considers inefficiencies and losses associated with electricity generation and transmission.</td>
<td>By 20xx, develop an optimized system with
– passive desiccants processing latent load-outdoor air
– active desiccants processing latent load-indoor load
– downsized "sensible only" conventional cooling space</td>
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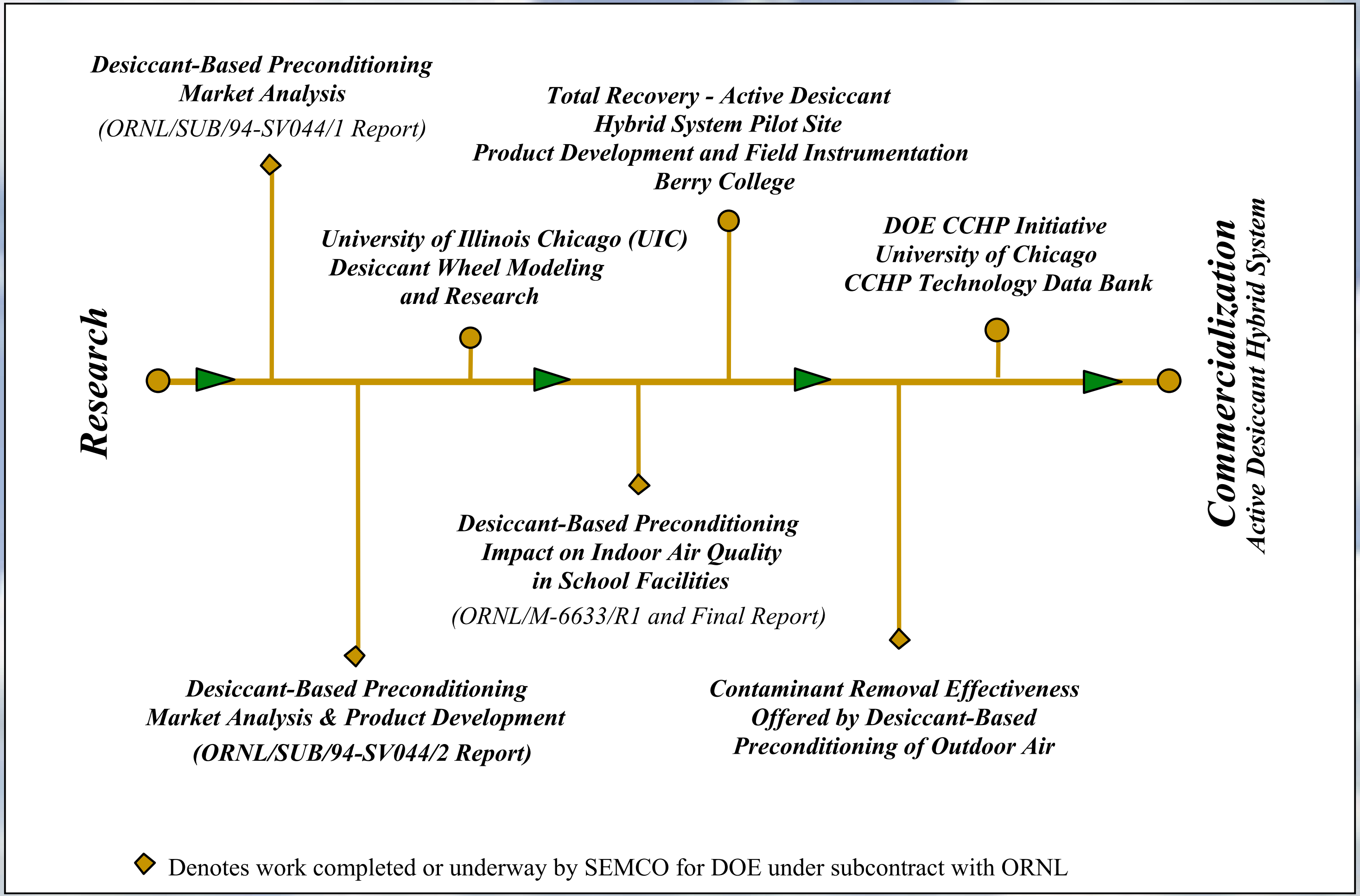
Logical Path to Commercialization



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Summary

- A cost effective, compact, energy efficient and fully integrated active desiccant rooftop (IADR) has been developed that can be regenerated with direct fired gas or low-grade waste heat (CHP)
- The IADR can process any percentage of outdoor air, deliver any SHR, can be operated as a VAV system and can include total energy recovery
- Field testing is underway with strong pull from the marketplace including large national accounts
- Continued product development, pilot testing and commercialization will take place in 2004

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Where from here?

- Patent in place for ADM and IADR, planning underway for commercialization in 2004
- Additional pilot project installations needed in key market segments, including CHP integration and IAQ testing
- Packaged rooftop performance screening tool, load analysis, space humidity and IADR selection software
- ORNL CHP test lab data to benchmark IADR CHP performance and system integration with power source
- Heat pump integration in IADR